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An Inexpensive Photoelectric Remote Tilt Meter

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An inexpensive remote reading level capable of indicating and recording tilt components can be assembled from a photoresistor and indicator lamp aligned in a tube containing a mercury surface. The device is useful to determine corrections needed for readings of meteorological equipment mounted on portable towers or in aircraft.

Retrieval Terms: Tilt meters, meteorological stations, remote sensing.

Most radiometers and anemometers are designed for installation on level (horizontal) bases. For wind vanes and cup anemometers, this requirement is absolute; there is no way to correct the output of the instrument for base tilt. For other sensors such as radiometers and hot wire anemometers, a correction can be applied if the tilt is known in terms of the azimuth and inclination, or as the tilt in the north-to-south plane and in the east-to-west plane.

For conventional meteorological stations, instrument leveling is a straightforward application of a carpenter's level, but in two situations this approach cannot be used. First, many portable meteorological towers are either impossible or dangerous to climb on a routine basis. Because of the flexibility of the linkages and guys in such equipment, however, the orientation of the tower base may differ considerably from that of instruments at the mast tip. Second, although direct observation of aircraft orientation is usually possible, many changes in orientation are likely to occur in short periods of time. A recordable tilt output is therefore almost mandatory for aircraft-mounted equipment.

Except for gyroscopic sensors, which are in general bulky and complex, the tilt gages currently available on the market are either (1) strain gages attached to pendulum weights, or (2) electrolytic sensors in which the position of the fluid surface relative to two electrode pairs indicates the tilt. The strain gage systems are generally quite temperature sensitive, and have outputs in the microvolt range. The electrolytic sensors require alternating-current bridge measurements, which present complications in field use.

A simple and relatively inexpensive solution to the measurement of tilt components under field conditions was devised for use with portable towers. It may be operated from battery power and supplies a d.c. voltage output in the 1-volt range without significant lead effects at distances as great as 100 m from the actual sensor position.

CONSTRUCTION OF THE LEVEL

The level is shown in cross section (*fig. 1*). The tube (T) is a 4-inch section of PVC (polyvinyl chloride) pipe, inside diameter 5/8 inch, as commonly used in lawn irrigation systems. The pipe is fitted with two of the PVC couplings sold with such systems (M and N). A 1-inch diameter disk of translucent polyethylene plastic (D) fits between the end of the pipe section and the interior flange (J) of the

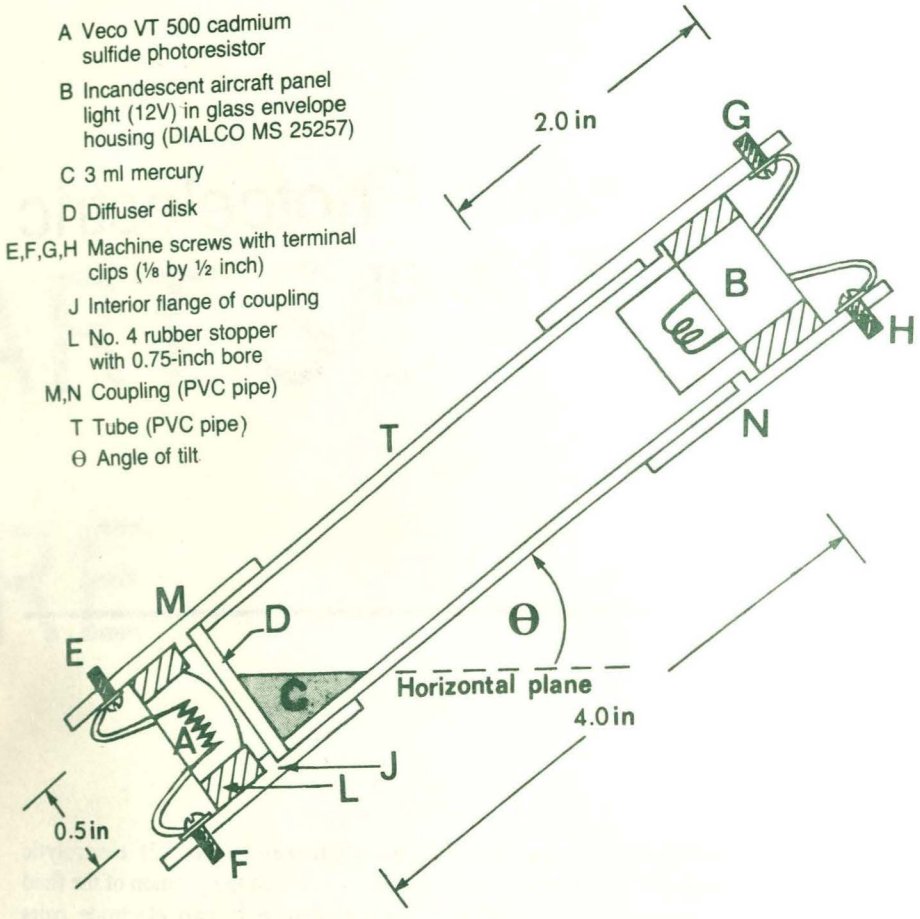

Figure 1—The components of the level are readily available, and are combined as shown in the schematic diagram.[1]

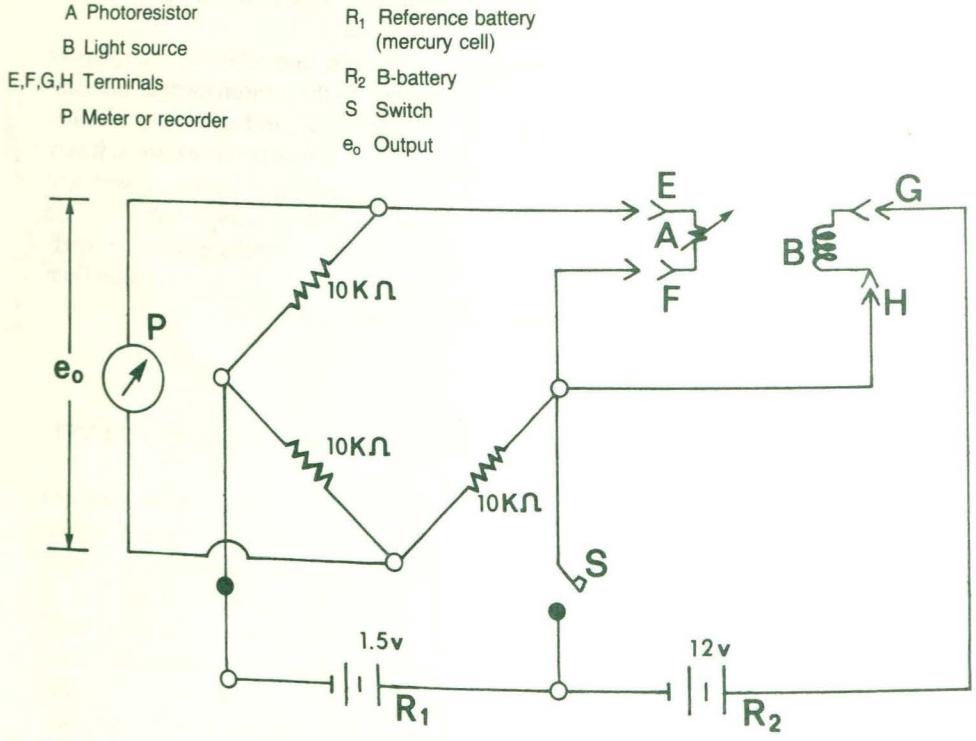

Figure 2—A simple bridge circuit may be used to provide continuous tilt output from the level.

coupling. This disk is cut from a typical polyethylene bottle with a 1-inch cork cutter; it snaps firmly into place with a concave profile. The disk serves to diffuse the illumination incident on a cadmium sulfide photoresistor (A) held in the outer end of the coupling by a number 4 rubber stopper (L) bored with a 3/4-inch hole. Light is provided by a 12-volt aircraft panel light (B) similarly mounted in a rubber stopper. The leads for the photoresistor and the bulb are attached to machine screws in holes drilled through the coupling walls. The level is filled with 3 ml of clean mercury (C) and sealed with rubber cement.

As the tube tilts towards the photoresistor, an increasing fraction of the disk (D) is covered by the mercury and the light intensity at the photoresistor surface decreases, with a consequent increase in the resistance of A. The resistor used has a "dark resistance" of 100 KΩ which falls to less than 1.3 KΩ at 100 foot candles of illumination.

For tower leveling, the level can be included in a "null" bridge circuit. For continuous tilt output, as in aircraft applications, a simple unbalanced bridge circuit (*fig. 2*) may be used.

ACCURACY AND SENSITIVITY

The photoresistor resistance has a temperature coefficient of about 0.4 percent per degree Centigrade;[2] therefore, any appreciable temperature effects on sensor output would be due to the resistance changes in the birdge circuit component, if one is used, or to variation of the battery output supplying the bulb filament. Both the bridge circuit and the battery are, however, remotely housed from the sensor itself.

Because of its radial symmetry, the level is sensitive only to tilt in the vertical plane of the tube axis; rotation about the axis does not change the mercury surface position relative to the disk (D).

Sensitivity to moderate vibration is unlikely. At the levels of illumination supplied by the light bulb used, the frequency response of the meter is limited, however, by the effective lag time of the photoresistor—about 0.1 s.[2] A "sloshing" effect would be anticipated for vibration frequencies greater than about 20 cps.

CALIBRATION

A number of levels were constructed and calibrated on the vernier head of a machine lathe; a typical calibration curve was plotted (*fig. 3*). The range of readings for five levels with the circuit shown in *figure 2* and an inclination of 30 degrees was from 0.650 to 0.800 volts. The sensitivity varied between the five levels from 0.0260 volts deg^{-1} to 0.0290 volts deg^{-1}, decreasing with decreasing outputs at the 30-degree position.

In the 25-degree interval centered at 30 degrees, the calibration is reasonably linear (*fig. 3*). To take advantage of the linear region centered at about 30 degrees, the tubes were mounted at that angle to the horizontal plane (*fig. 2*). Because the orientation of a surface or instrument axis is specified by two tilt components, the levels were deployed in pairs; one aligned east to west and the other north to south.

Although relatively simple in design, the level depends on complex optical phenomena, such as the reflections of the light emitted at point B (*fig. 1*) between the tube walls and mercury surface. Therefore, because calibration is such an easy task, the levels should be individually calibrated.

NOTES

[1]Trade names and commercial enterprises or products are mentioned solely for necessary information. No endorsement by the U.S. Department of Agriculture is implied.

[2]Ferroxcube Corporation. 1960. *Photoresistor characteristics*. Bulletin EB-12B, 8 p.

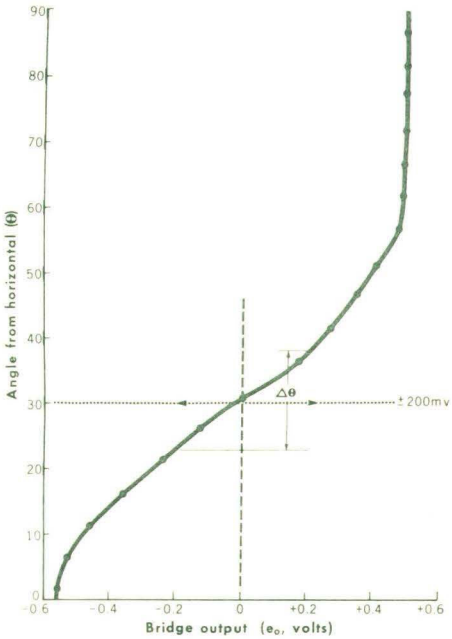

Figure 3—A typical calibration curve for the level gives a linear region centered at 30 degrees.

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